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Enhancing the pH Value of Black Soil using Electrokinetic Remediation Technique

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Abstract

Electrokinetic Remediation (EKR) is a low-cost, effective, and environmentally benign process for removing multiple heavy metals from damaged soil at the same time. It entails placing electrodes into the soil around the contaminated area and delivering a low voltage to the electrode, causing pollutants to migrate to the electrode by electromigration, electroosmosis, and electrophoresis. Soil pH is a key aspect that can influence the effect of EK remediation on contaminated soil restoration. Using varied voltages for 6 weeks, this study determined the change in pH value in acidic to neutral soil. Before EKR, the pH of black soil was 4.5, and it increased in a variety of patterns depending on the treatment duration. The greater the curing day of the treatment, the higher the pH value of the black soil. The suggested duration and voltage for EK remediation are 14 days and 20V, respectively. One of the criteria that can affect soil pH while utilising EK therapy is the strength of the applied voltage.

1. Introduction

Electrokinetic Remediation (EKR) had been proven as a relatively cheap, effective, and environmentally friendly technology for the simultaneous removal of multi-heavy metals in polluted soil [1]. Soil pH is an important factor which can influence the effect of EK technology on the remediation of contaminated soil. The pH value determines the chemical form of the compounds present in the system and the transport processes of these compounds. Soils and groundwater contaminated by inorganic pollutants including heavy metals, radioactive elements and inorganic salts pose considerable risks to the environment and humans because of their potential toxicity [2]. Initially, the electrokinetic projects focused on the removal of metal contamination and other inorganic anions. The technique is very effective in the removal of inorganic materials and organic materials from black soil. Thus, EKR is a developing technology which intends to separate and extract inorganic and organic contaminants from contaminated soil like black soil.

This treatment has proven its efficiency in consolidating organic, peat and clayey silt as well as less expensive than other methods. Also, it focuses on how to improve soil pH value and quality of soil to be used in slope, plantation, and other sectors. In this review, we can present three objectives that need to be achieved to increase the pH value of black soil by using an electrokinetic remediation technique. These are to investigate the physical and chemical characteristics of black soil through moisture content, compaction and pH, to evaluate the

pH value and curing day of black soil using electrokinetic remediation (EKR) and to investigate the suitable voltage used in the electrokinetic remediation process (EKR). This study is expected to increase the pH value of black soil from acidic to alkaline condition on the 14th day. This study's main aim is to employ Electrokinetic Remediation (EKR) to raise the black soil quality such that it may be used by people from a variety of sectors.

Soil pollution is caused by two types of pollutant named organic and inorganic. The soil contaminated by inorganic contaminants including heavy metals, radioactive elements and salts has been posing risks to human health and the ecological environment, which has been widely paid attention to in recent years. The electrokinetic remediation (EKR) technology is recognized as the most potential separation technology, which is commonly used to clean sites that are contaminated with organic and inorganic contaminants. The types of organic pollutants that are frequently found in soils are polychlorinated biphenyls, polybrominated biphenyls, polychlorinated dibenzofurans, polycyclic aromatic hydrocarbons, organophosphorus and carbamate insecticides, herbicides, and organic fuels, particularly gasoline and diesel. The inverse log of the hydrogen ion concentration on a scale from 0 to 14 is used to calculate soil pH, which is a measure of soil acidity or alkalinity. Acids are substances with a pH below 7 while bases are substances with a pH of 7 to 14. The neutral pH is about 7. A pH of roughly 6.5 is ideal for the majority of cultivated plants. The process of soil remediation is very important to prevent our soil from being polluted. Therefore, many methods or techniques are used to do this recovery process.

According to a study on the Electro-Kinetics process of Remediation of clayey soil contaminated with nickel nitrate using an enhanced Electro-Kinetics process and a study of the geotechnical properties of the remediated soil samples. The contaminated substance discovered in their investigation is nickel nitrate; after recovering it using the Electro-Kinetics procedure, they discovered that the removal effectiveness of nickel metal measured using an atomic absorption device was between 31.3 and 43.2 percent. So, what are the advantages that users will get if they use this electrokinetic remediation process? The advantages of using electrokinetic stabilisation are cost-effective, applicable to apply in-situ and ex-situ, rapid installation, easy to operate, silent operation, does not disturb site activities, and has a short treatment duration. It can be concluded that this treatment has proven its efficiency in consolidating organic, peat and clayey silt as well as being less expensive than other methods [3]. There are several parameters involved in Electrokinetic Remediation (EKR), which are the pH value of soil, voltage usage, curing days, and distance of electrode used in Electrokinetic Remediation (EKR). Next, investigated copper removal from soil using the EKR technique [4]. The experiments were carried out by supplying a direct-current electric field of 15 V throughout the soil using a transparent Perspex model with stainless steel electrodes. The duration of each copper removal experiment is 3, 7, and 14 days, respectively.

2. Materials and Methods

In general, the main method we use in this study is the electrokinetic method and the properties to be studied is the pH value and curing day of black soil to turn neutral.

In the first stage, the black soil will be collected and pre-processed before being used in the experiments. Physical, mechanical and leaching tests have been conducted in detail to identify the characteristics of all the materials used in this research. In the second stage, the top of the soil to a depth of 1 meter will be removed to avoid taking the humus, waste and plant roots. The soil will be characterised using three main tests which are initial pH, moisture content and compaction using a standard proctor test. The third stage, the laboratory setup for Electrokinetic Remediation (EKR) consisted of a transparent acrylic tank measuring for easy monitoring of the electrokinetic process. The design setup will be modified based on studies by the previous researcher with a dimension of 22cm x 5cm x 10cm for the main middle compartment [5] [6] as shown in Fig. 1(a) and Fig. 1(b).

In the fourth stage, to achieve our three objectives which are to investigate the physical and chemical characteristics of black soil through moisture content, compaction and pH. Furthermore, to evaluate the pH value and curing day of black soil using electrokinetic remediation (EKR). Next, to investigate the suitable voltage used in the electrokinetic remediation process (EKR). Stage 5, the curing day towards the sample soil pH enhancement, the final pH value of the sample soil, and the suitable and effective voltage used in Electrokinetic Remediation (EKR) will be known after the remediation experiment is conducted. The data from the physical tests will be analysed, modelled and tabulate in graphs and tables using software applications namely Microsoft Excel and Microsoft Word.

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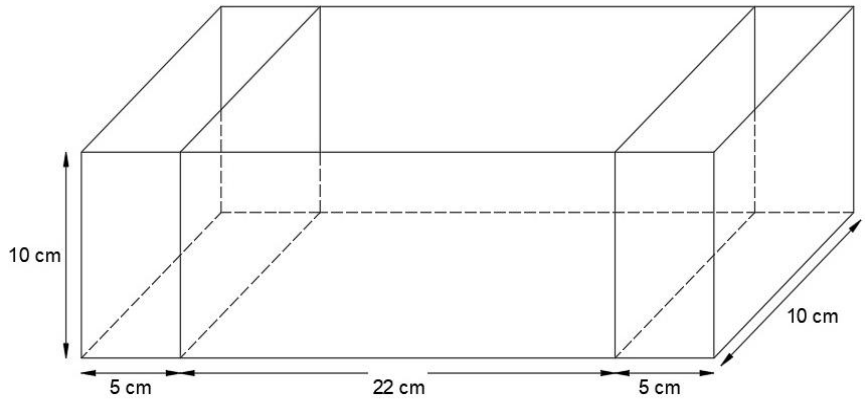
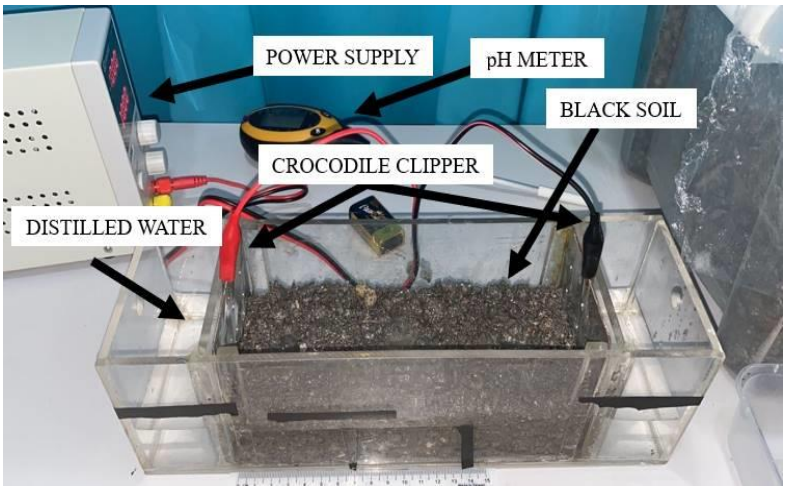


(a)



(b)

Fig. 1 *(a)Schematic Diagram of EKR for Laboratory Setup, and (b) Actual Diagram of Laboratory Setup*

3. Result and Discussion

The results of laboratory experiments have been analysed and presented in tables and figures. They are divided into 4 main components: physical characterization of raw material, chemical characterization of raw material, and the relationship between pH value, curing day and voltage. The first two components describe the properties of raw materials, while the third discusses the evaluation of the pH value of black soil using electrokinetic remediation (EKR).

3.1 Physical Characteristic of Raw Material

The physical properties of the raw materials used were investigated at this stage. The Atterberg limit test, the specific gravity test, and the moisture content test are the physical specification tests that have been conducted. Each piece of data was collected and entered in **Table 1**.

Table 1 *Summary of the index properties of raw materials*

Testing	Soil
Optimum Moisture Content (%)	26
Specific Gravity	2.65
Liquid Limit, LL (%)	41
Plastic Limit, PL (%)	29
Plasticity Index, PI (%)	12
Maximum Dry Density (mg/cm3)	1.87

The optimum moisture content (OMC) and maximum dry density (MDD), which are 26 and 1.87 respectively, are also shown in the Table 2. The specific gravity of the soil is within the range of 2.1–2.7 for black cotton soils [7]. Based on the result obtained, the soil sample was classified as low plasticity Clayey SAND.

Table 2 *Atterberg limit characteristics of the soil sample*

Characteristics	Result
Liquid limit	41%
Plastic limit	29%
Plasticity index	12%
Soil type	Black, Silty Clay
Degree of plasticity	Medium Plasticity

Using electrokinetic remediation (EKR), the chemical specification tests for pH were carried out. With an initial pH of 4.5, it was discovered that soil is acidic. The tables also demonstrate that various voltage values were applied throughout the process of this experiment which are 10V, 20V and 30V.

3.2 pH vs Curing Day

In this study, the initial pH for black soil before Electrokinetic Remediation (EKR) is 4.5, indicating that it is acidic. The pH value increases in a variable pattern depending on the duration of treatment. The pattern concentration remained constant throughout the experiment, with the highest pH value occurring at the nearest cathode compartment (Area C) on day 14 of every phase of the experiment and the lowest pH value occurring at the nearest anode compartment (Area A) on day 1 of every phase of the experiment.

According to Fig. 2 (a), Fig. 2 (b), and Fig. 2 (c), the greater the curing day of the treatment, the greater the pH value of black soil. Furthermore, the results show that the pH value is closely related to the duration of treatment, with the pH value being highest on day 14 compared to days 1, 3, and 14. The day 14 sample result on phase 3 showed a significant trend in increasing the pH value, which is 10.8, 10.9, and 11.1 and the conditions are strongly alkaline. Even though the value of electric current during day 14 of phase 3 is higher compared to other durations of treatment, it is not recommended to use the same value as it can cause the black soil to become strongly alkaline and degrade the soil quality further. As it achieved the targeted pH value of black soil after remediation, the recommended curing day and electric current to use in enhancing the value of pH of black soil are 3 days and 20V since the pH value is 6.8, 7.2, and 7.4 which are just nearly neutral.

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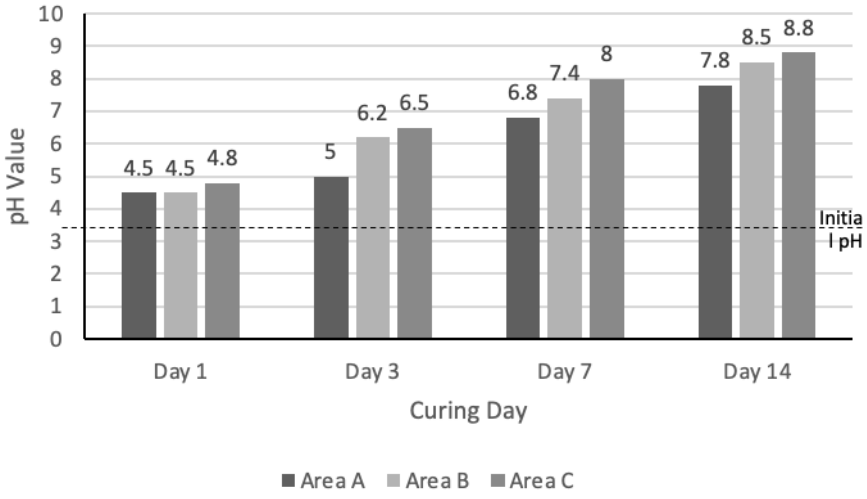
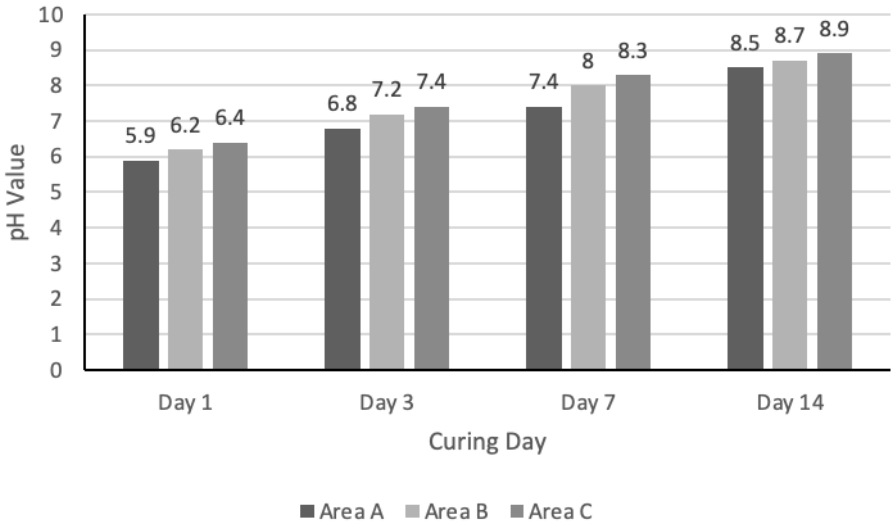


(a)



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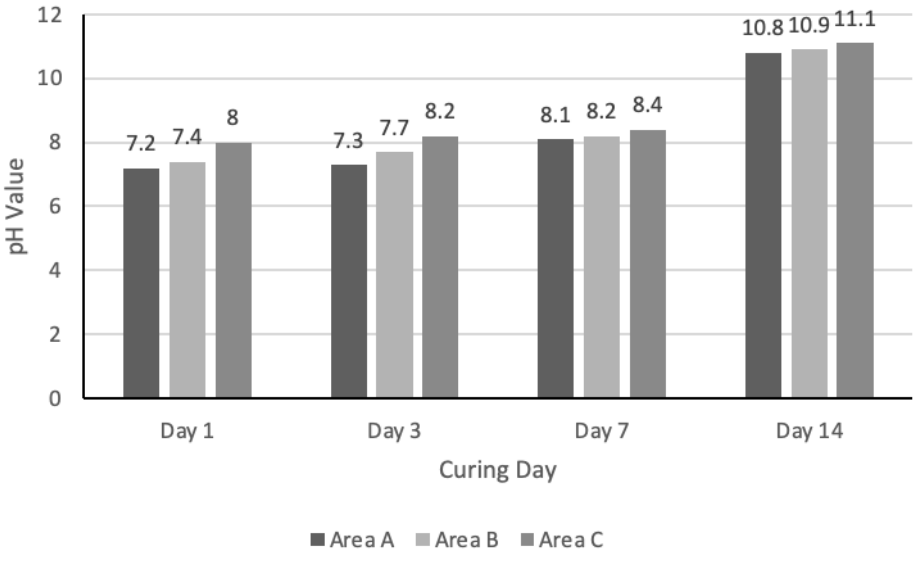

(c)

Fig. 2 *(a) Bar Graph of pH Value against Curing Day using 10V (Phase 1), (b) Bar Graph pH against Curing Day using 20V (Phase 2), and (c) Bar Graph of pH against Curing Day using 30V (Phase 3)*

Fig. 3 shows the relationship between curing day and pH value. Generally, the figure shows an increase in curing day when there is an increase in pH value. This is because the condition of black soil that is acidic takes time in conducting the EKR test to turn neutral. The application of electrokinetic recovery in copper removal is suitable for a short period and further combined techniques should be considered to increase the removal percentage [8].

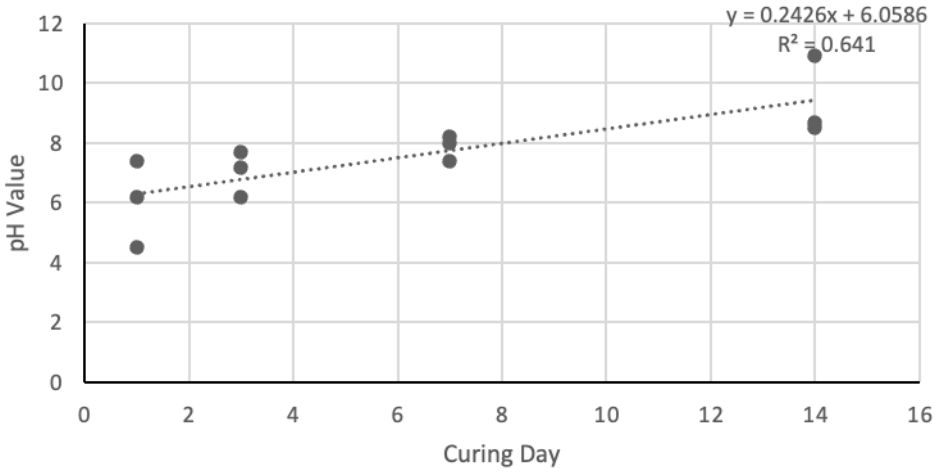

Fig. 3 *Graph of Relationship between Curing Day and pH Value*

3.3 Voltage vs Curing Day

Based on the data presented in the diagram, Fig. 4 shows the pH change of black soil after EKR for 14 days**.** It shows that the pH reading on day 14 is the highest for the EKR test at 10V, 20V, and 30V voltage. On the first day the value reading was done, the pH value of the soil was still in an acid state for the EKR test at 10V and 20V voltage while at 30V voltage the soil had become neutral on the first day of taking the pH value reading.

Furthermore, the pH value at 30V voltage is greater than the pH value at 10V voltage. This is because the 30V voltage is too high to run the EKR test, and 30V is not suitable for converting acidic black soil to neutral because it causes the black soil to become strongly alkaline. Finally, the voltage of 20V is the best result for performing the EKR test on black soil because it is a moderate and the best voltage rather than 10V and 30V. As a result, a voltage of 20V is ideal for performing EKR tests on black soil from acid to neutral. The best results in terms of overall cell removal and specific energy consumption were obtained under the following conditions: (i) effective voltage of 14.6 V (VDC = 10 V and VAC = 15 V), (ii) AC voltage frequency 1000 Hz, (iii) electrical field applied in pulses with a time ratio of 25 [9].

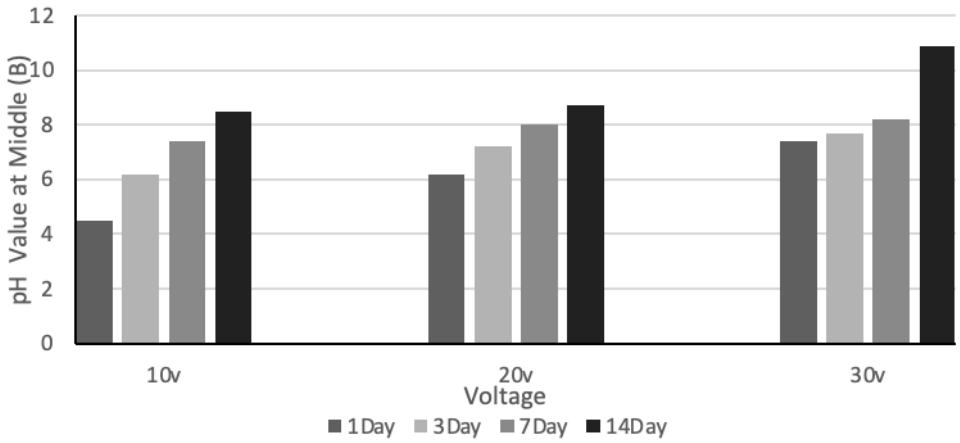

Fig. 4 *Bar Graph of pH Against Voltage Respectively with Curing*

4. Conclusion

This study discovered that by utilising varied voltages for 6 weeks, the electrokinetic process can convert acidic soil to neutral soil. Before Electrokinetic Remediation (EKR), the pH of black soil was 4.5, and it increased in a variety of patterns depending on the treatment duration. The suggested duration and electric current for EKR is 3 days and 20V, respectively. Increased shear strength determines EK efficiency, however, the strength of the applied voltage can impact soil pH.

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Conflict of Interest

The authors declare that there is no conflict of interests regarding the publication of the paper.

Author Contribution

The author confirms sole responsibility for the following: study conception and design, data collection, analysis and interpretation of results, and manuscript preparation.

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